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# LBNF Target Exchange System

## - Design Progress

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In conjunction with FNAL Target Systems Department

NBI Fermilab 2019

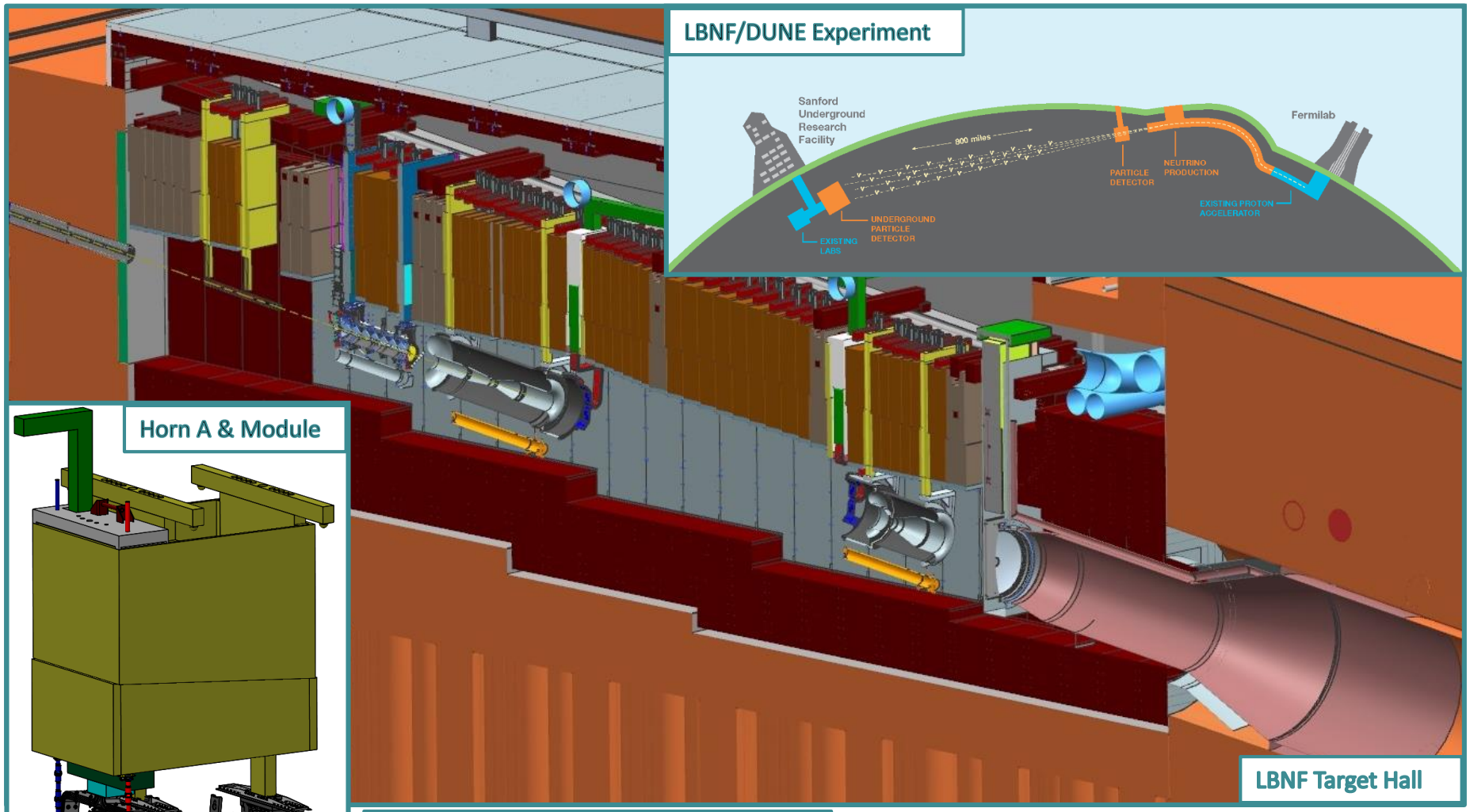
Fermilab
Long-Baseline Neutrino Facility

DUNE
DEEP UNDERGROUND NEUTRINO EXPERIMENT

Science & Technology Facilities Council

High Power Targets
www.STFC.ac.uk

# LBNF Neutrino Beamline







Horn A & Module: most of the important interfaces between RAL and FNAL

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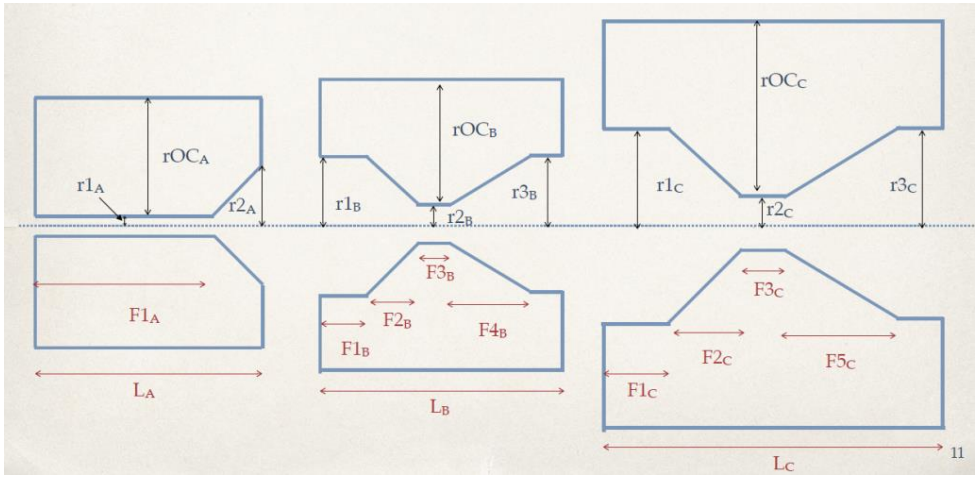
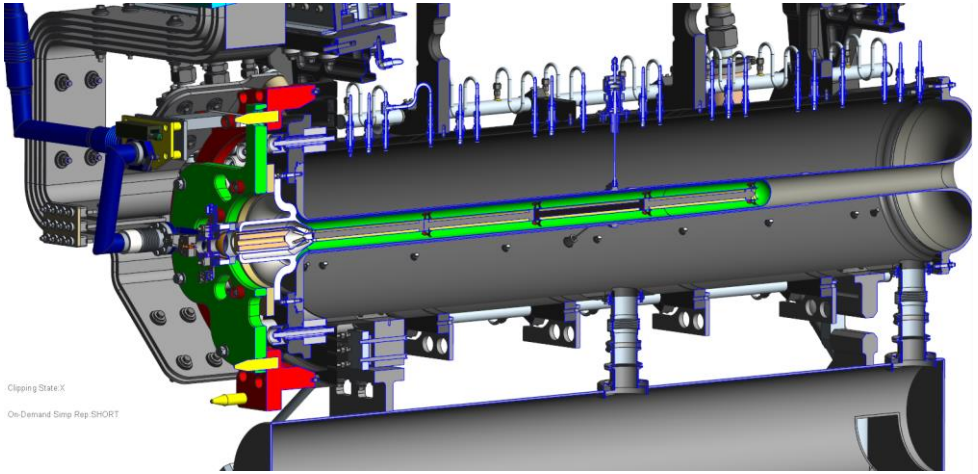
# Why Do We Need To Exchange Targets?

- Horn & Target configuration for LBNF/DUNE optimised using genetic algorithm (Laura Fields)
- Optimum geometry for physics tends towards 4λ length target (≈2m)

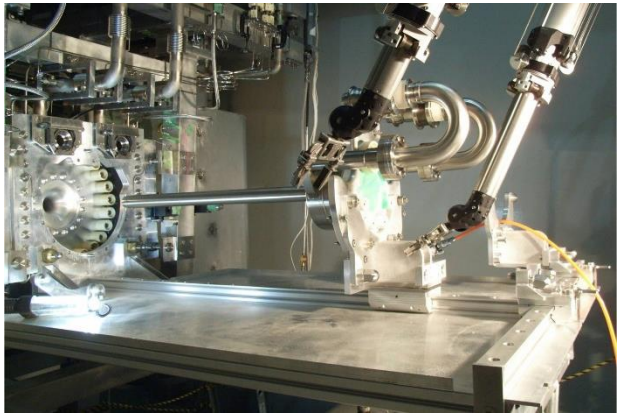
- Achieving a long target pushes fundamental limits (deflection, natural frequency, manufacturing etc.)
  - Must be prepared for targets to fail

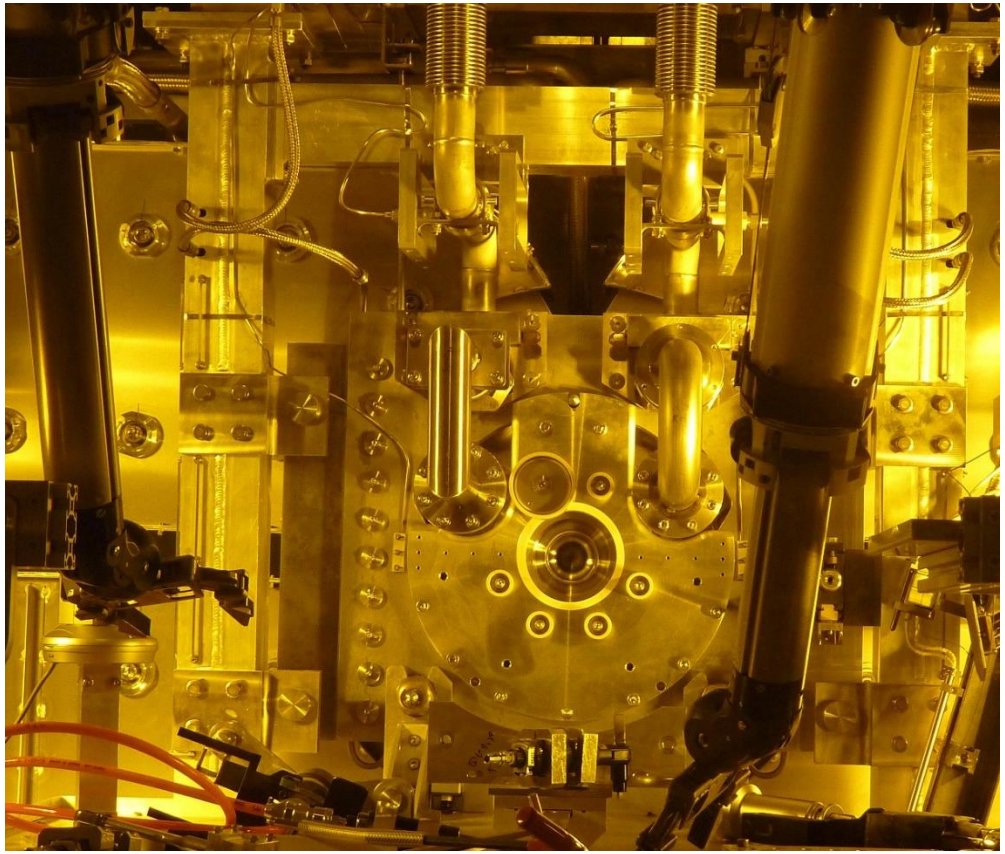
- Horns are inherently complex, costly and take a long time to produce
- Target cost ≈1/10$^{th}$ horn cost, and spares can be produced more readily
  - Hence the need for an independently exchangeable target



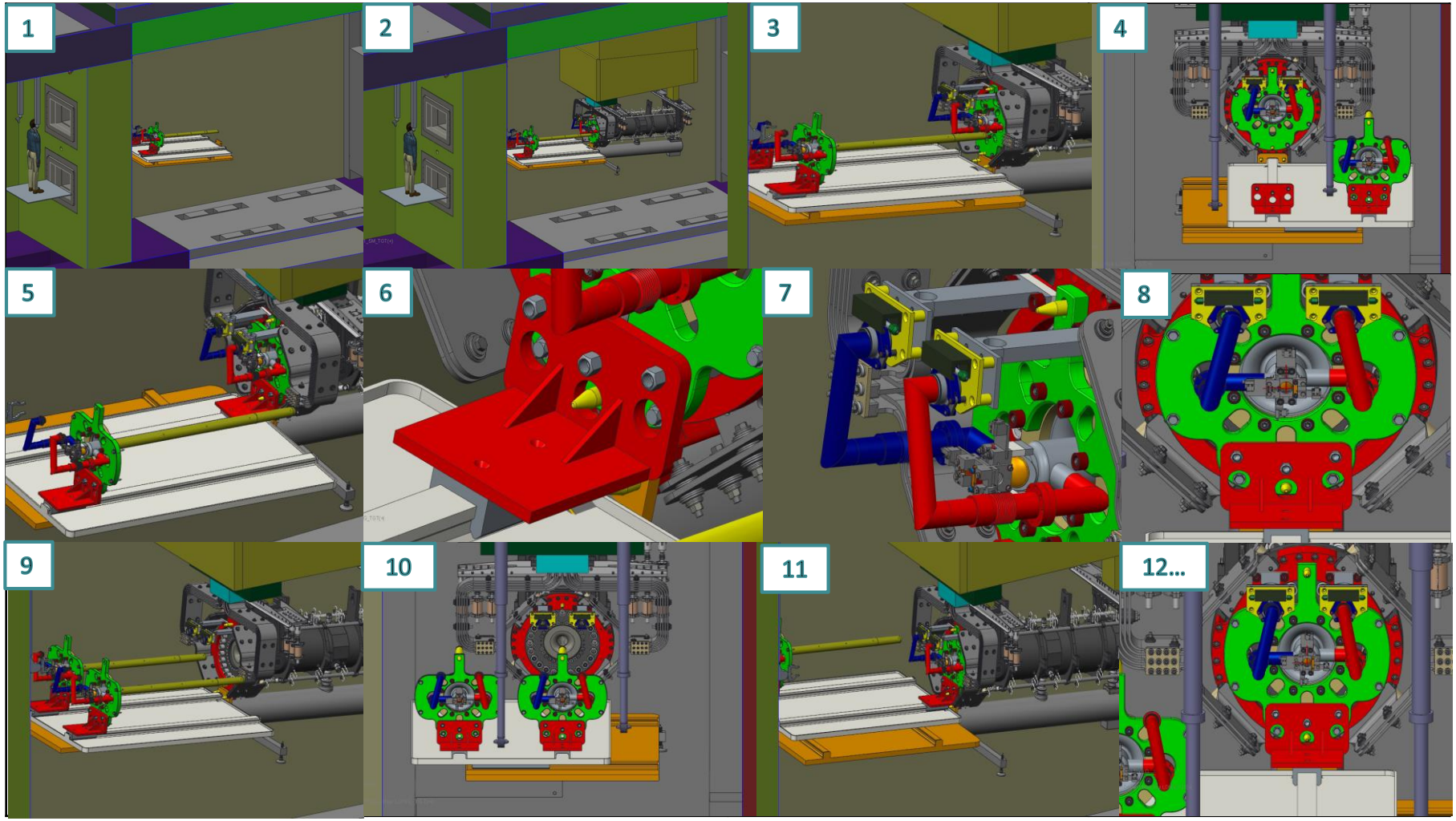
# Current Experience – T2K





- LBNF target exchange is a similar concept but under different constraints
  - Longer target, different exchanger interfaces, more horn bore clearance
  - Experience from T2K will feed into LBNF exchanger design

# Conceptual Procedures for Target Exchange



# Target Concept Selection

Target exchange impacts were a key consideration in the LBNF target concept selection:

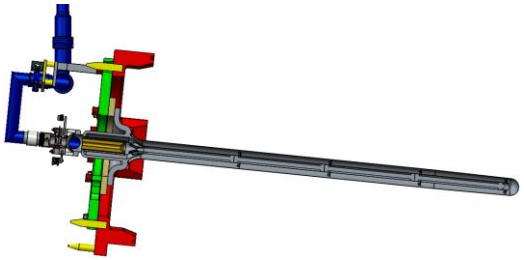
Target exchange was considered for each concept including:

- Procedures required
- Risk associated with target exchange
- Time taken to exchange target system
- Impacts on the work cell requirements

**2.2m supported target**

**Double target**

**Single cantilever target**



# Target Concept Selection

| Option | No. Operations | Target Handling Time (Days) |
|---|---|---|
| 1) 2.2m Supported Target | 41 | 22 |
| 2) Double Target | 35 | 14 |
| 3) Cantilever Target | 18 | 5 |

*John Back's assessment calculates an extra 13-19 days running per year with a single cantilever target to achieve same theoretical physics performance as a 2.2m supported target*

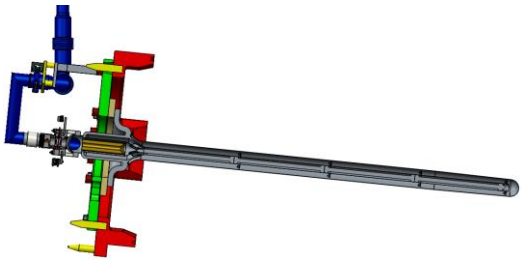
A single cantilever target was selected as providing the optimum performance:

- Small hit in instantaneous physics versus a longer, downstream supported target, but;
- Instantaneous physics hit likely to be made up in integrated performance due to a more robust design
  - Simpler target is less likely to fail in operation
  - Takes less time to replace outside of a planned maintenance schedule

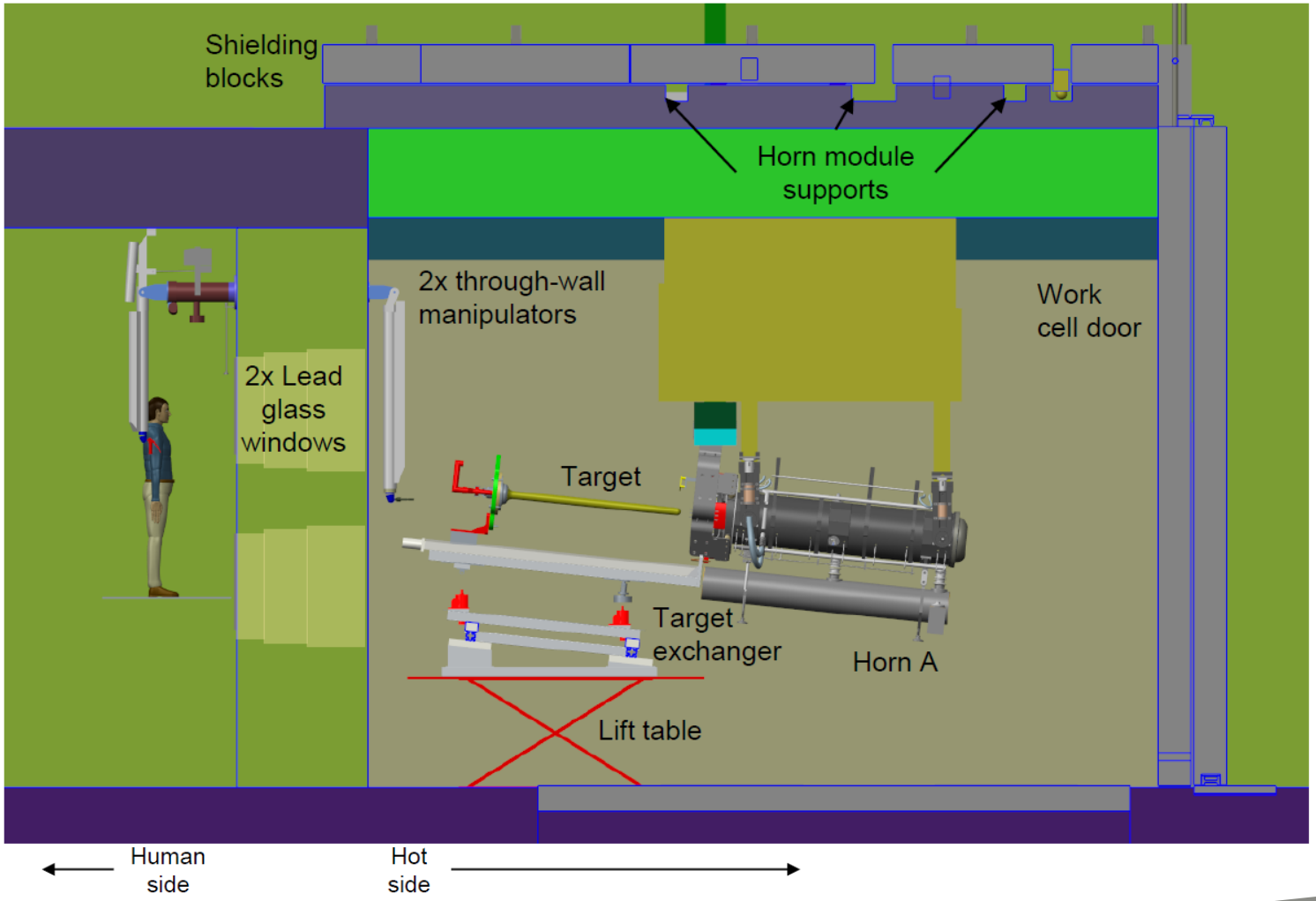
**2.2m supported target**

**Double target**

**Single cantilever target**



# LBNF Work Cell During Target Exchange

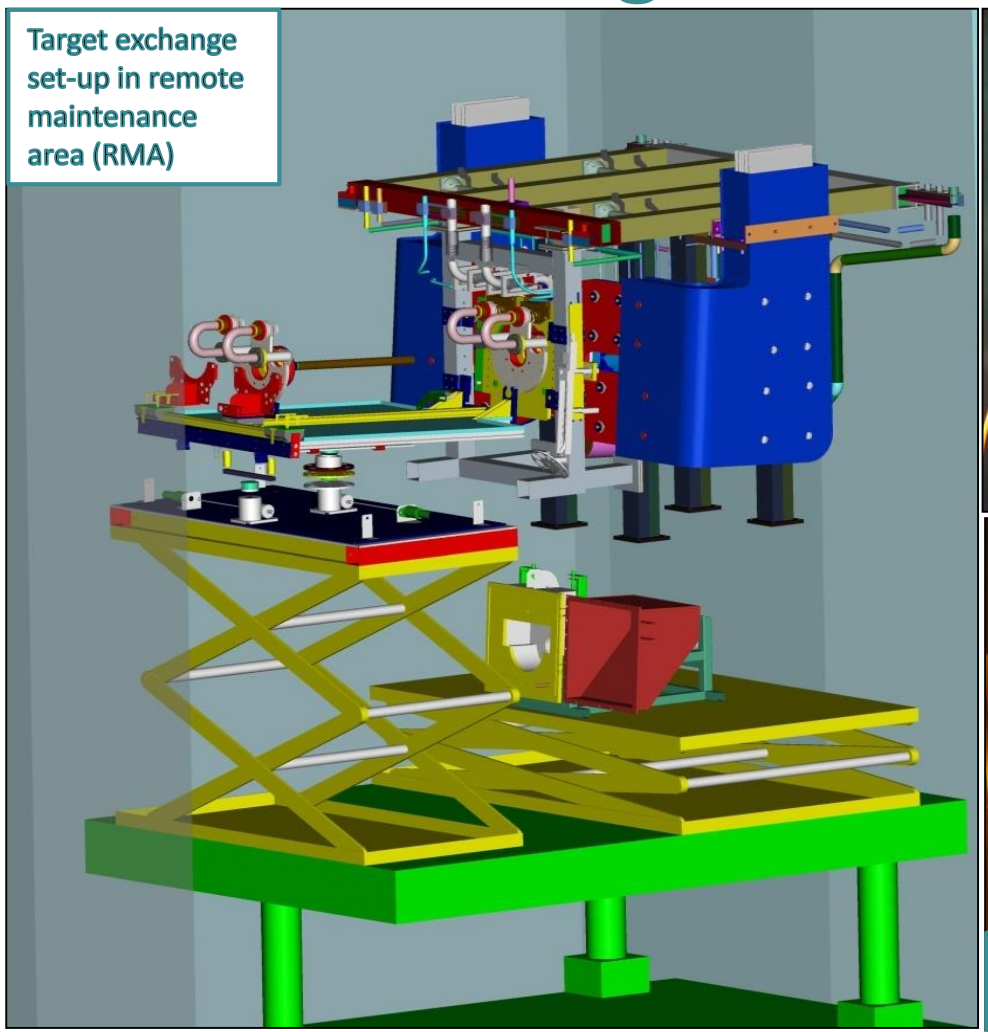



Horn module supported from the top of the work cell

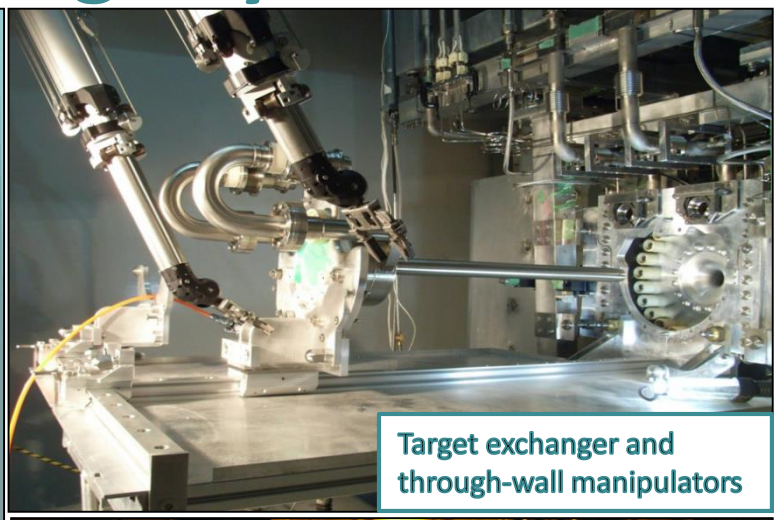
Target exchanger located on lift table on work cell floor

Persons using through-wall manipulators are approximately 4m away from the front face of the horn

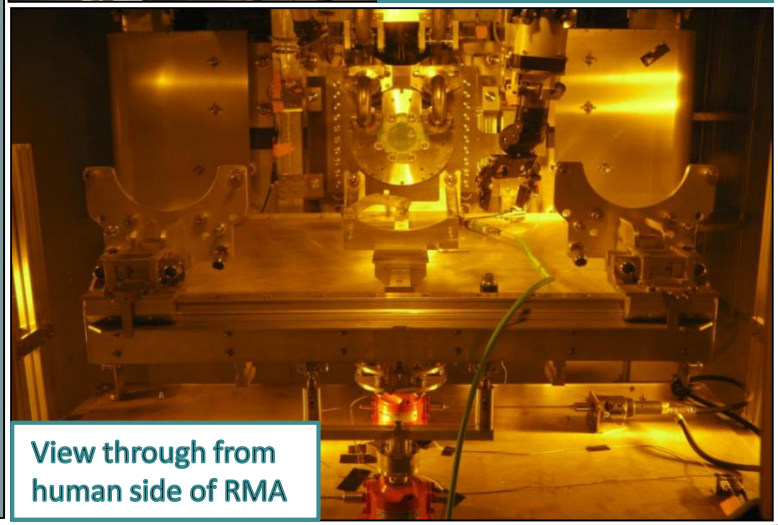
# T2K Target Exchange System



Target exchange set-up in remote maintenance area (RMA)

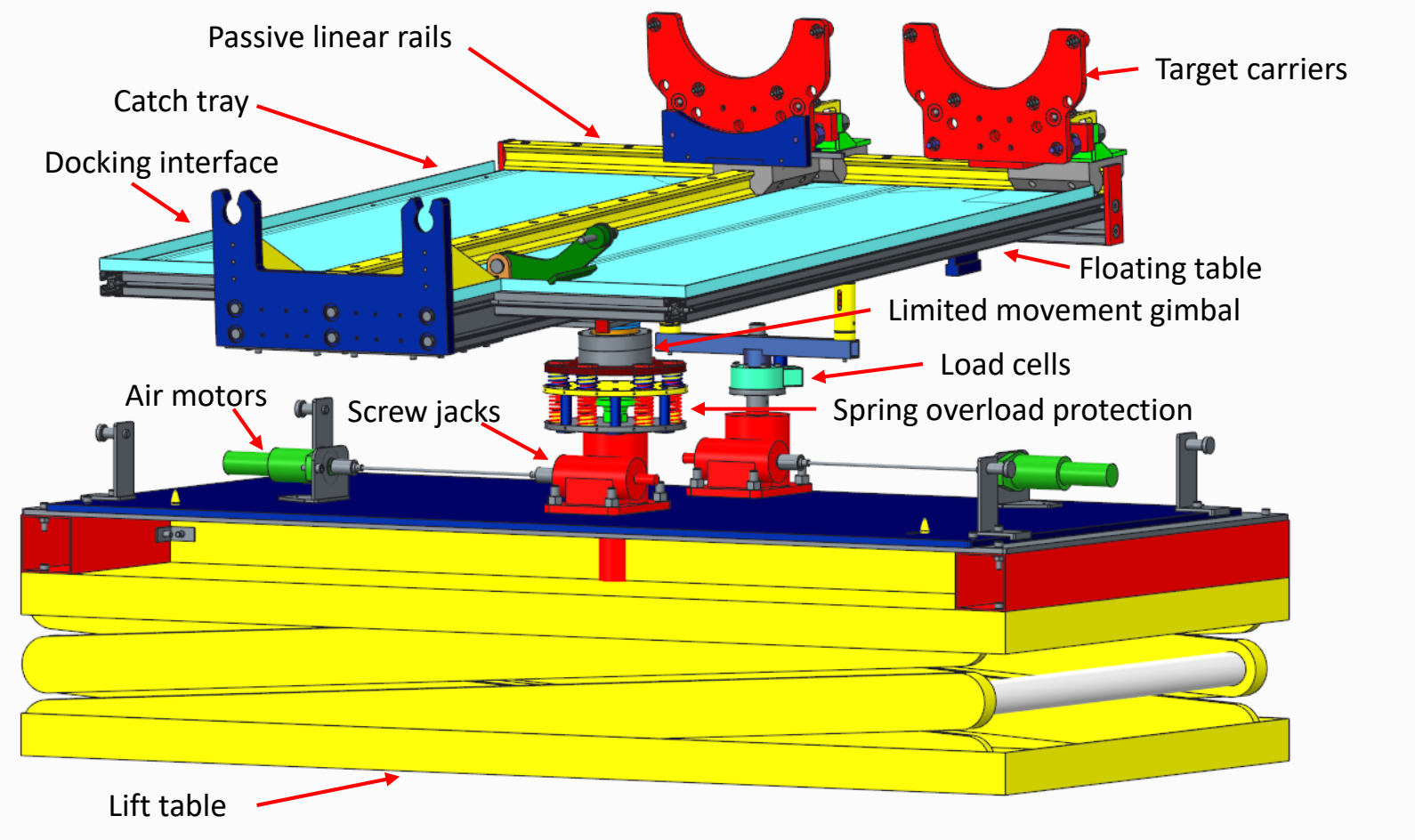


Target exchanger and through-wall manipulators



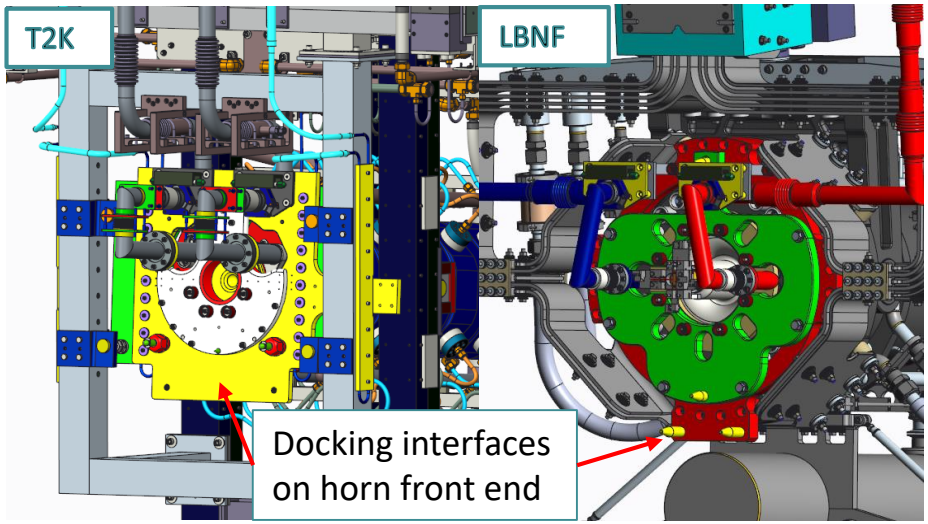
View through from human side of RMA

# T2K Target Exchanger



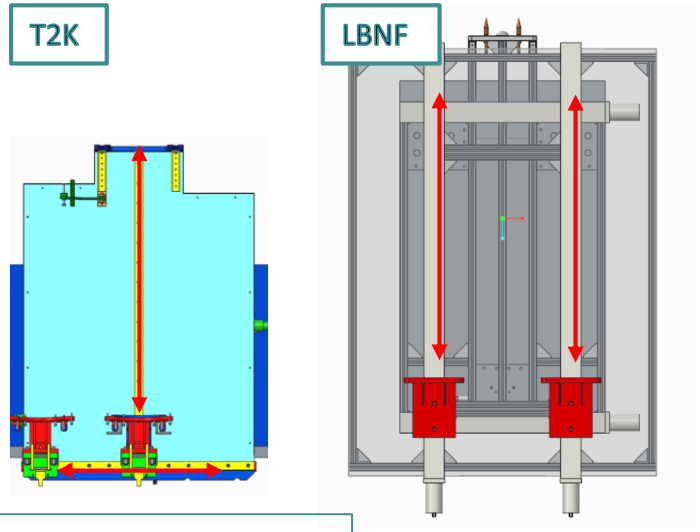
# Some Differences for LBNF

- Length of target exchanger
  - T2K Target 0.9m (1.7m exchanger)
  - LBNF Target 1.5m+ (2.8m exchanger)
- Docking interface
  - T2K relies on perpendicularity of several interfaces
  - Limited "real estate" on LBNF
  - LBNF supports are not a robust datum for alignment
  - **Potential for large moments to be applied to horn A**



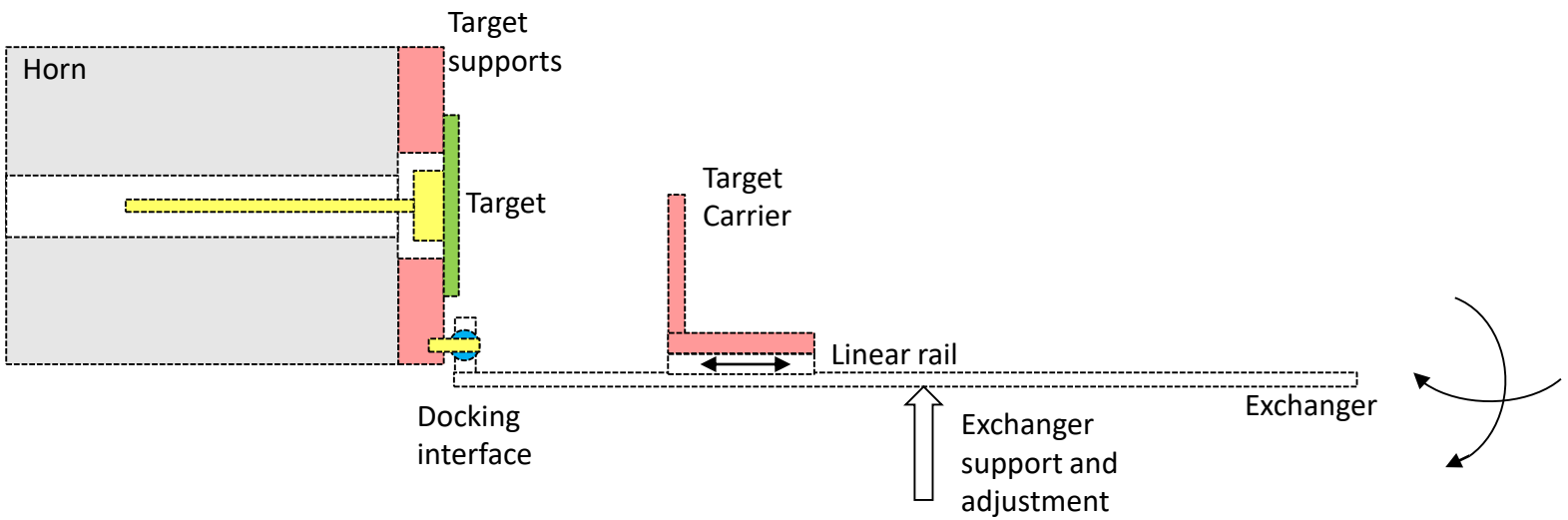

***→ "Hard" mechanical docking/alignment likely not possible for LBNF***

- Cross rail system
  - Moving target from "x" rail to "z" rail is fiddly and time consuming
- Passive rails
  - Range of motion required to push or pull target carriers along rails would be excessive for LBNF



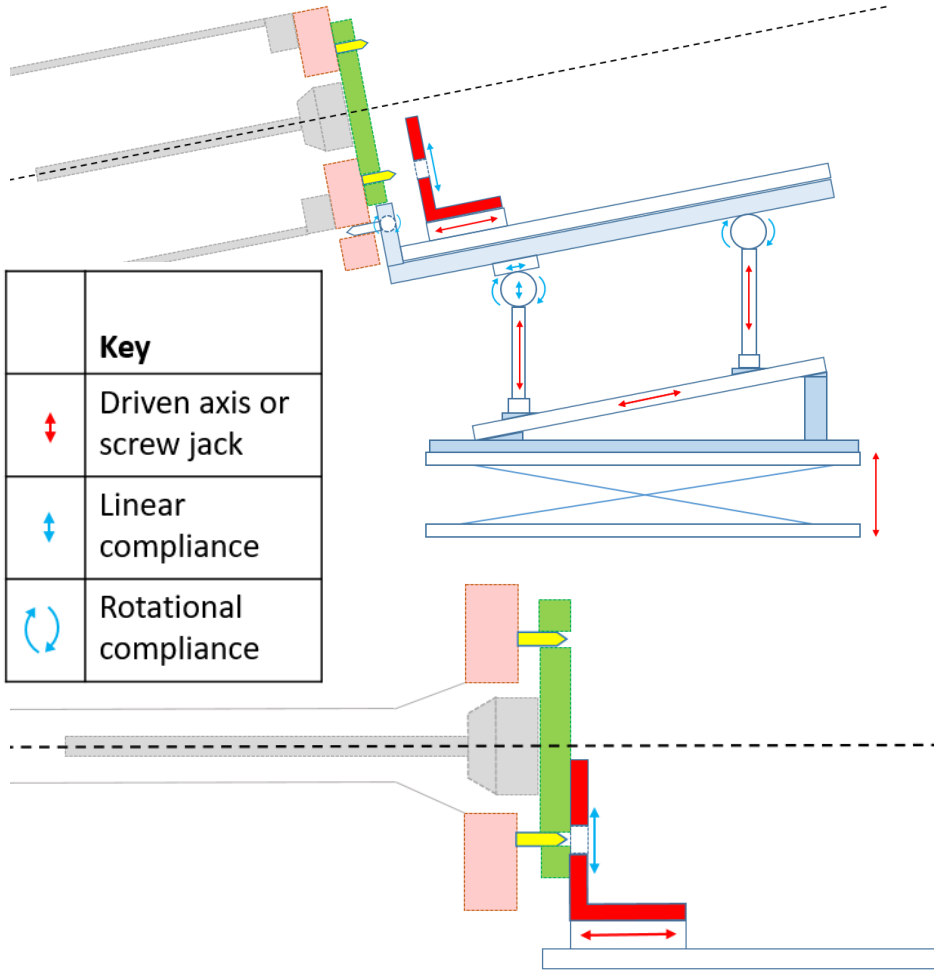

***→ Use motorised linear rails for LBNF target exchanger***

# LBNF Target Exchange System Concept



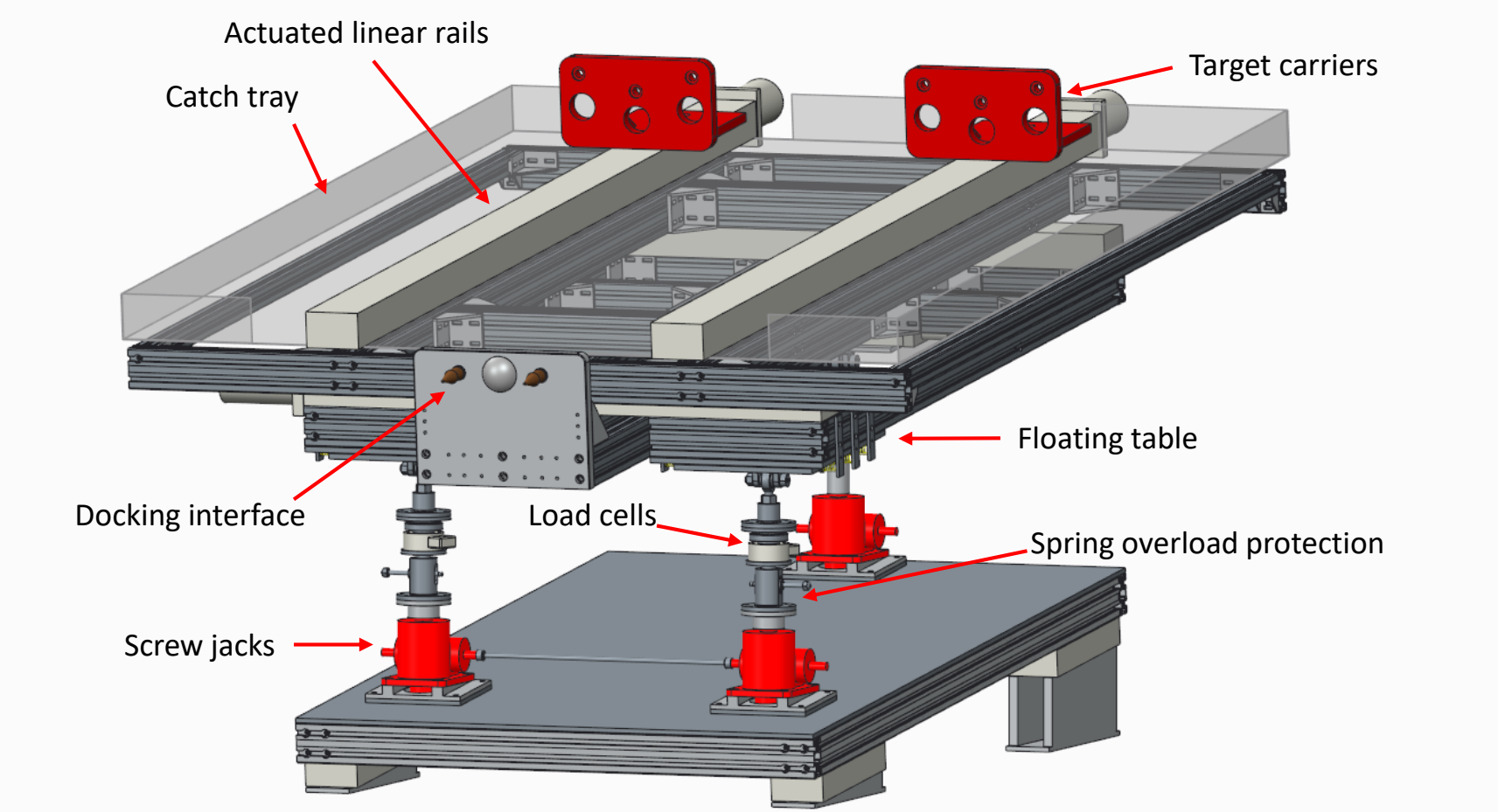

- Dock exchanger @ target supports to accurately fix position at front end of exchanger
- Allow some rotation about that position to align the exchanger axis to the horn bore axis
  - Alignment diagnostics may be challenging – investigating triple beam interferometers/autocollimators for laser alignment
  - Sensitivity/accuracy of these systems may be no better than a “hard” mechanical alignment but the risk of damaging other systems is reduced

# LBNF Target Exchange System Requirements




- Horn module suspended from the top of the work cell
- Exchanger located on lift table on work cell floor
  - Relative positions not well defined
- Horn tilted at approximately 6° from horizontal
- Exchanger must have sufficient compliance to allow location pins at front end to align
  - Compliance must be well controlled such that the exchanger is not unstable
- Driven jacks/linear stages must allow fine adjustment to align the exchanger slides to the horn bore
- Target carrier must have some small in-plane compliance to allow target to locate on its alignment pins, but must not allow angular rotation
  - Target must clear horn bore without touching

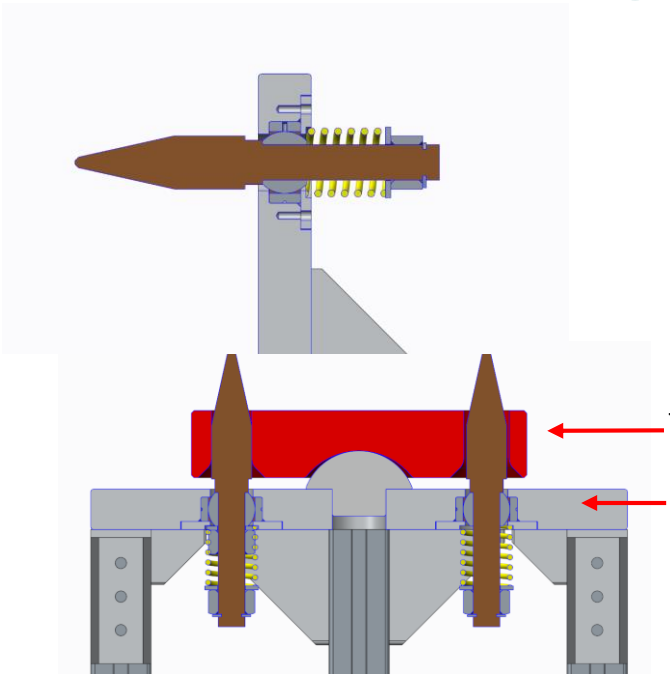
# Potential Layout

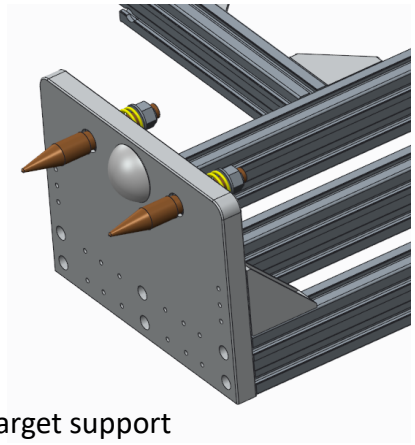


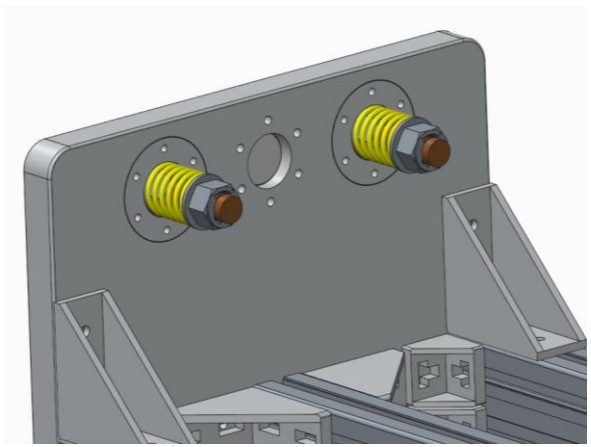

***Challenges:***

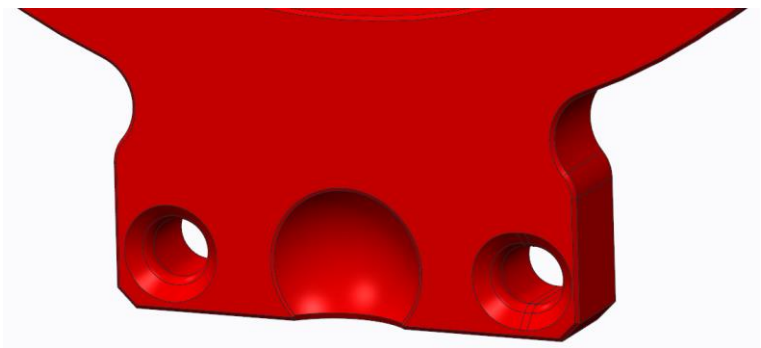
- ***Stiffness/mass trade-off***
- ***Minimising complexity***

# Docking Interface Ideas







- Spring centred location pin on spherical bush
- Tapered hole/slot in target supports
- Spherical stop to fix separation between exchanger and target supports but also permit small rotational adjustments after docking
- Still need a method of securing the exchanger to the target supports

***Layout of pins/holes may change - Prototyping of interface will be necessary***

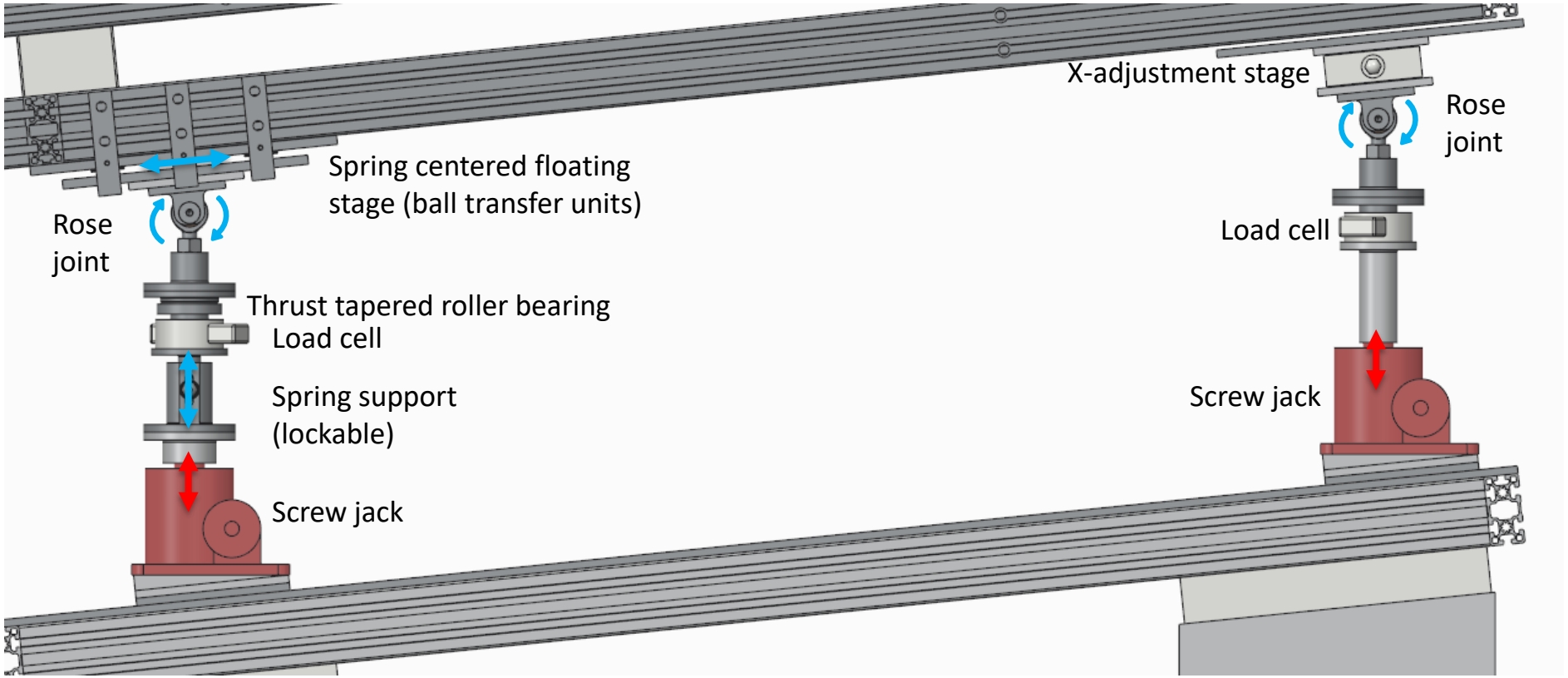
# Summary

- The LBNF secondary beamline will use a remotely exchangeable target
- The procedures for exchanging targets have been developed and documented
- The concept for an LBNF target exchanger is being developed into preliminary design ideas
  - Plenty of R&D still to be done
- Lessons learnt from the target exchange system for T2K are being implemented in to the LBNF design
- Based on T2K experience we expect to go through a few iterations before we have an exchanger suitable for “on-line” target exchange
  - Current schedules show that this will be possible

# Backup - Schedule

- RAL Schedule currently has exchanger testing during summer 2024
- Approx. 6 months allocated to redesign prior to delivery to FNAL
- Feb 2025 earliest possible date for actual integration and exchange testing with Horn A on test stand at FNAL
  - Assuming this schedule is correct, there are several years available to iterate and potentially improve exchanger prior to an “on-line” target exchange
  - This will also allow scope for FNAL RH technicians to develop and become familiar with procedures

# Backup - Exchanger Table Supports




***Challenges:***

- ***Flexibility/stability compromise***
- ***Maintaining simplicity***